# Landfill Gas

Can waste be more useful than simply recycling it? Yes. This module will briefly discuss the formation of landfill gas, the technologies that utilize landfill gas, and the comparison of multiple technologies.

When we mention the word “landfill,” it usually relates to the waste that cannot be used further or recycled. Now science has made the waste even more useful. The generation of landfill gas, which is primarily composed of methane and carbon dioxide, can power machines that create electricity. First, take a moment to read about the process of landfill gas formation. There are five processes to generate landfill gas:

*1. Aerobic Decomposition*
In this step, bacteria will decompose the waste along with the consumption of oxygen. Carbon dioxide and heat are released. This process may last from months to a year.

*2. Acidogenic*
Since most of the oxygen has been consumed at this point, an anaerobic, or lack of oxygen, condition establishes. Under this condition, $H_2$, $CO_2$, $H_2O$, and organic acids are produced. The energy released is relatively low compared to aerobic decomposition.

*3. Acetogenesis*
In this step, acids and alcohols are oxidized to form acetic acids, $CO_2$, and $H_2$. Higher concentrations of oxygen are required for oxidation to take place.

*4. Methanogenesis*
Methane is produced from the products of acetogenesis by consuming Hydrogen gas ($H_2$).

*5. Maturation*
At this last point in the process, most of the substrates are depleted, and only a limited amount of gas is produced.

The production of landfill gas posts two problems: first, high concentration of methane may lead to auto ignition, or combustion; second, emission of methane will cause an increased greenhouse effect. However, if the landfill gas is used as fuel, these two problems can be eliminated.

There are several technologies that use landfill gas as fuel to produce electricity:

1. <u>Reciprocating Internal Combustion Engine (ICE)</u>
The ICE is the main technology used for electrical energy generation by landfill gas. The risk of employing ICE is very low because the technology has been consolidated, and the cost of operation is relatively low. ICE has a compact size that

makes it very easy to transport. The trade-off is that it has a high emission of toxic gases, such as $NO_x$ and carbon monoxide (CO).

2. Gas Turbine (GT)

The second most used technology in electricity production is the gas turbine. There are fewer GTs than ICEs, due to the GT's lower efficiency and higher fuel consumption. However, GTs emit less toxic gases into the atmosphere than does an ICE.

3. Stirling Cycle Engine (SCE)

High fuel impurity often limits performance of other technologies. SCE overcomes this limitation because the impurity actually helps the engine perform better! SCE emits only small amounts of toxic gases into the atmosphere, but the disadvantage is the huge engine size.

4. Molten Carbonate Fuel Cell (MCFC)

MCFC offers several advantages over the other landfill gas technologies. It does not require any metal catalyst for electrochemical reaction, and it utilizes carbon monoxide as fuel. The high temperature working environment (650ºC) allows the fuel cell to tolerate higher concentrations of impurities. There is no noise emission, only trace amounts of toxic gas emissions, and has about 50% efficiency in energy conversion. However, MCFCs have high capital costs that discourages intensive development.

5. Solid Oxide Fuel Cell (SOFC)

SOFC offers similar performance as compared with the MCFC. SOFC has an even higher working temperature, about 800-1000ºC. As mentioned, higher temperatures allow for higher impurities in the fuel. However, the high temperature does have a negative effect on the fuel cell, namely: increase in cost, decrease in durability, and decrease in technology robustness.

The table below summarizes data collected from each technology mentioned.

| | ICE | GT | SCE | MCFC | SOFC |
|---|---|---|---|---|---|
| Electric efficiency | 33% | 28% | 39% | 50% | 50% |
| Fuel consumption (kJ/kWh) | 10972 | 12872 | 9390 | 7174 | 7174 |
| Emissions (µg/kJ) | | | | | |
| $NO_x$ | 56.6 | 15 | 3.11 | Trace | Trace |
| CO | 56.6 | 19 | 15 | 1.4 | 1.4 |

**Sources:**

Bove, Roberto; Lunghi, Piero. "Electric power generation from landfill gas using traditional and innovative technologies." *Energy Conversion and Management*. **2006**, *47*, 1391-1401